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THE AMERICAN
METEOROLOGICAL JOURNAL.

VOL. VI. ANN ARBOR, JULY, 1889. NO. 3.

ORIGINAL ARTICLES.

STORMS AND A CENTRAL ASCENDING CURRENT.

BY PROFESSOR H. A. HAZEN.

The theory of an ascensional current in the centre of a storm was first proposed, or at least greatly enlarged, by Espy in 1835. This theory has more general acceptance than any other to-day, and is second in importance only to the theory of the increase of energy through the liberation of latent heat and consequent production of a partial vacuum. On these two depends the whole science of theoretical meteorology. It is proposed to discuss a few of the arguments for and against these theories.

1st. The tendency of all surface air currents is toward a central region of low pressure, hence, if there is no uprush of air, this region of low pressure would rapidly fill up and the storm come to an end.

2nd. An ascending saturated column will occur whenever the rate of decrease of temperature with increase of hight in the undisturbed surrounding air is greater than that in the column.

3rd. An uprush may also occur at times by a greatly heated lower stratum suddenly breaking through a cooler stratum above, or, in other words, whenever there is a very abnormal decrease of temperature with hight in a rather quiescent mass of air.

4th. Espy's whole argument was based on the fact that any precipitation could only occur through the condensation of moisture in an uprushing current, and that the ascending current and resulting precipitation were both at the centre of the disturbance.

5th. There is a partial vacuum at the centre of a disturbance, and hence there must be an uprush of air into it.

6th. Great masses of material are frequently carried into the air, especially in tornadoes, and this could only be done through the aid of an uprushing current.

7th. It has been claimed that the apparent bursting of a house, whereby the four sides are thrown outward, proves the existence of a partial vacuum, and the necessity of an uprushing column of air is established by this vacuum.

These are all the arguments, so far as I know, in favor of an ascending current. The most important fact, and one repeated again and again, is that this uprush can only be at the centre of disturbance. It would seem as though the general tendency of the winds toward the centre and the bendings of the isobars about the same point show unmistakably that here and here only can any considerable uprush take place if there be an uprush at all. At all events even if there are minor effects which may be traced to sporadic uprushes elsewhere than at the centre, yet the fact must still remain all the more emphatic that precisely the same effects must be produced in a much more marked degree at the centre where the uprush, if there is any anywhere, will exhibit its greatest effect.

Here are some of the proofs that there is, and can be, no uprush of air at the centre of a disturbance:

1st. There is little or no rainfall at that point, at least in this country. The bulk of our rain falls at a distance of 300 or 400 miles to the eastward of the centre. This fact has been recognized, and attempts have been made to explain away its force by the hypothesis that the rain drop is actually formed at the centre of the storm, but is carried by the rapid upper currents to great distances before it falls. This hypothesis is not tenable, however, for the reason that gravity would cause the drop to

reach the earth at a distance of less than a mile, even under the most extreme conditions. Papers eight inches square have been dropped from a balloon at the hight of 10,000 feet, where the current was not far from 30 miles per hour, and these have reached the earth within a mile horizontally of the point of release. It has been repeatedly observed, that after a vivid flash of lightning, allowing a few seconds for the drop to fall through gravity, there has been a great down-pour of rain directly under the thunder peal. This fact has been used as an argument by some who think that rain is caused by the release of electric tension upon the molecules of moisture, thereby allowing them to coalesce. This may be regarded as a most positive proof that after a rain drop has been fairly well formed it must fall within a hundred feet unless it is evaporated by the drier air beneath. The theory is a convenient one, but does not accomplish its purpose.

2nd. Thunderstorms, tornadoes and other local outbursts do not occur at the centre but about 400 miles to the southeast and where there is no uprush of air whatever.

3rd. Such an uprush of air, if at all considerable, it is very easy to see, would entirely obliterate the bendings of the isobars in a very few hours, no matter what assistance may be invoked from the condensation of vapor or overflowing of the air. We are in great danger of forgetting that the extreme hight of this column of ascending air rarely exceeds a mile or a mile and a half and all the air rushing in must be disposed of. Observations have shown that the upper current at the hight of about a mile is almost steadily from the west, and any augumentation of a considerable amount to this current would very speedily change the distribution of pressure and bring about a result entirely negatived by our synoptic charts.

4th. If we consider only saturated air, which at about 80° diminishes 1° in 500 feet of hight, we are met by a singular complication. As long as the air is saturated and quiescent the above relation holds, but when condensation has taken place, if for the sake of argument we admit that this has occurred, then we find a tendency to an unsaturated air and the relation no

longer holds. In fact, it seems to be beyond question that there can be no precipitation as long as latent heat is set free and becomes sensible, for this would immediately become latent again by re-evaporating the moisture. This shows plainly that, unless the latent heat is radiated into space, converted into electricity, or disposed of in some way, precipitation would cease almost immediately. It is certain that it will not be accepted that this latent heat can be converted into electricity, and it is more certain that it cannot be radiated into space through the clouds. But there is a still more important consideration. It is admitted by all theoreticians that the storm circulation and uprush of air would quickly cease if it were not for the partial vacuum formed by the liberation of latent heat, so that, if this latent heat does not become sensible, it is admitted that the storm could not exist.

5th. The most essential point in an uprising column is that it shall be vertical or nearly so. It is very plain, indeed, that no column could exist or develop energy if it were inclined even 30° to the vertical. The rising current can only take place from the fact that the air in it has a less density than the surrounding air and the action can only be in a vertical direction. It is very plain, however, that since the upper currents have a greater velocity than those a mile lower, the uprushing column will be very quickly inclined much more than 30°, and the whole effect would quickly cease. The attempt has been made to avoid this difficulty by the consideration that the upper part of the storm is continually reforming itself as it advances and communicating its motions to the lower air. This certainly seems one of the most strained hypotheses ever advanced. It inevitably breaks up the essential continuity of the ascending current. It attempts a rapid vertical action through different strata in a frictionless medium, which is impossible. It cannot be accepted as anything but a convenient theory and one which does not accomplish its purpose.

6th. The whole theory of an unstable equilibrium in the atmosphere seems to be dependent upon very unsatisfactory assumptions as to the diminution of temperature with hight. It

is certainly not a fact that a column of air, uniformly diminishing in temperature for a hight of two miles, is surrounded by air having another rate of decrease in temperature. On the east side of the storm the currents are quite uniform from the south and southeast, or heated, while on the west they are from the north and northwest and much cooler. This at once shows the impossibility of the condition assumed. Such a distribution of temperature, at least if the uprushing column were dependent upon it, would very quickly tend to break up all uniform conditions of diminishing temperature. But this is not all; we are told that a theoretical computation of the diminution of temperature with hight in an unsaturated air column at about 80° temperature is 1° per 280 feet, while in a saturated air it should be 1° in 500 feet. It is difficult to see just how the gradation between saturated and unsaturated air can be maintained with such an enormous theoretical difference, but granting that it can, we still see that in actual practice no such conditions as the above are observed. Dr. Hann has tried to show, by observations at high level stations in Europe, that the diminution of temperature in the centre of a storm and where the air is saturated is very much greater than in the dry air of a high area. His deductions, which are so emphatically contrary to the above theory, are based upon an entirely erroneous use of observations. The truth, however, still negatives the theory. A study of forty storms and high areas which have crossed Mt. Washington in the winter season have shown the following facts:

HIGHT IN FEET IN WHICH TEMPERATURE DIMINISHED 1°.

	Theory.	East Side.	Center.	West Side.
High	180	290	300	450
Low	280	450	460	290

This table shows a great difference between theory and observation on Mt. Washington, and such as cannot be explained away. It is plain that the mountain side would affect the temperature slightly, but this would be a small matter. Balloon observations alone can settle this question, and these, so far as made, give

absolutely no help to this hypothesis. It is probable that when a storm is crossing any point the temperature during the day time changes little or none up to 2000 or 3000 feet. When the cloud is reached the temperature continues the same, or is a very little less for several hundred feet, but as the top of the cloud stratum is reached the temperature rises enormously, and after the cloud is passed the fall is about 1° in 300 feet in sunshine.

7th. It seems impossible to consider that there can be vertical columns of air of different density in a frictionless medium. While balloon observations have shown horizontal strata of cloud of different temperature in the atmosphere and an insensible gradation from one to the other, and cloud observations have shown the same, yet the case is very different with a vertical column, where the tendency of the air would be to restore the equilibrium at once, and it is probable that no differences in density could be maintained, even if they could be begun at all, in a vertical direction in a column of air a mile in hight, for more than a few minutes.

8th. How can the rushing of boards and debris into the upper air be accounted for except by an uprushing column? I think there is a frequent misconception of this condition, and many suppose that these objects rush into the partial vacuum which nature is supposed to abhor. If we think a moment, we shall see that even if a perfect vacuum should surround a stone or stick it would remain immovable, and in fact it would be less buoyed up by the exact mass of air equal to its own bulk. Even if this vacuum extended to the limits of the atmosphere, the condition would still remain. The only possible way in which the stone can be moved is by the rush of air flowing over and around it. Now, it is a very frequent observation that dust, leaves, branches, etc., are carried to a considerable hight by winds which are by no means abnormally great. So it is entirely probable that with the very high winds of a tornado objects of great weight may be carried to some hight. Certainly it is not at all necessary to assume that a partial vacuum must exist before this can happen, and as we have just seen, the only way in which this can act is by inducing a very high wind.

9th. Finally, the apparent bursting of a house can be explained without resorting to the vacuum theory. It will be found that while the four sides *appear* to go outward yet this is not the case. At Wallingford, Conn., there was one of these seemingly exploded houses, in which the N., E. and W. sides were thrown outward, but the S. side was forced in under the roof, and both were almost directly over the cellar. This house stood on the north side of the track, and the appearance was precisely the same as though the tremendous velocity of the wind had forced in the south side like the blow from an enormous club, and the compressed air within had forced out the other sides of the house. Still another explanation is that an electrical charge increases the air pressure within the house and produces a seeming bursting.

CONCLUSIONS.

1st. The present theories of storm generation and development are exceedingly unsubstantial and will not bear scrutiny.

2d. Meteorology needs quantitative analysis and positive computations of cause and effect.

3d. More than that, it needs, above all things else, positive information of the processes going on in the upper air strata.

4th. There can be no release of latent heat by precipitation and subsequent increase of energy through the partial vacuum induced.

5th. It seems probable that the processes of storm formation are almost wholly independent of temperature distribution in a vertical direction.

6th. There is no marked vertical ascending air column in a storm centre and, if there were one it would very rapidly bring the whole process to an end.

7th. The winds which blow about a storm centre are radial, or nearly so, at the outside, but gradually become more and more tangential and at the center are exactly so. This shows that there is no need of a vertical ascending current; it also shows that if there be any such current it can only take place at the centre of the disturbance or of the curves of the isobars.

8th. The storm is probably entirely independent of the motion of the upper current.

9th. Our storms are whirls in the lower atmosphere extending to an hight of 5,000 to 8,000 feet.

10th. The cause of storms is a mystery up to the present, but, reasoning from the behavior of thunderstorms, they have within them the force which keeps up their energy, and it seems most probable that this force is some manifestation of electrical action not thoroughly understood, but none the less real.

May 16, 1889.

THE ORGANIZATION OF THE METEOROLOGICAL SERVICE IN SOME OF THE PRINCIPAL COUNTRIES OF EUROPE.

By A. Lawrence Rotch,
Member of the German Meteorological Society, and Fellow of the Royal (London) Meteorological Society.

HOLLAND.

History and Organization.—The Royal Dutch Meteorological Institute at Utrecht, the official establishment for meteorology, which had been a private institution from 1849, was permanently established in 1854, under the control of the Minister of the Interior. The director is the eminent meteorologist, Professor Buys-Ballot, who first stated publicly in 1857 the relation between wind and atmospheric pressure in the law which bears his name.

The Dutch meteorological system has aimed from the beginning at combining reliable observations over the world with each other, and thus showing the disturbances of the atmosphere and their mode of propagation, and at obtaining from the logs of merchant vessels statistical results as to the best routes. There is a department for Land and another for Maritime meteorology.

Staff and Budget.—The whole Institute is managed by a director-in-chief, Professor Dr. C. H. D. Buys-Ballot; the section for Land Meteorology is directed by Dr. M. Snellen; the section for Maritime Meteorology is directed by Baron P. F. van Heerdt;

the Amsterdam office is in charge of M. van Hasselt and the newly established branch at Rotterdam is under M. Arkenbout Schokke. There are in addition, at the central office, a secretary, M. Visser, a meteorologist, M. Engelenburg (both civil engineers), clerks and servants. The director is professor at the University of Utrecht, and the chief of the Maritime section is an officer of the Royal Navy. The salaries of each of the directors is about 2,000 fl. ($1,100), and the total sum expended for salaries is about 19,000 fl. For current expenses, such as printing, instruments, etc., 11,000 fl. are appropriated, making an annual budget of about 30,000 fl. ($12,000).

LAND METEOROLOGY.

This department performs the following duties:

(1) Carrying on meteorological and magnetic observations and comparisons in Utrecht.

(2) Issuing daily weather reports.

(3) Superintending the Dutch meteorological stations.

(4) Conducting certain international work.

The Central Office.—This is situated on a hill called the Zonnenburg, rising from a canal in the southeast part of the city of Utrecht. It is a first-class station and has the following instrumental equipment: The barometers, placed at a height of 13 m. above the sea, are a normal siphon barometer, made in Utrecht, which can be read to .02 mm., an English cistern barometer and a Wild–Fuess cistern siphon instrument which is now used as the standard. There is a barograph made by Olland, having a float resting on the mercury in the short leg of a siphon tube and connected to a lever, which multiplies the motion of the float four times. This is registered each six minutes by a pen on the lever, upon a vertical revolving drum. The barometer tube is tapped automatically to overcome capillarity, and the expansion of the mercury is counteracted by the expansion of the brass fulcrum of the lever. A fixed pen traces the normal pressure. The ordinary thermometers are exposed outside a north window, protected by blinds on the east and west and by glass louvres. In the thermograph of Krecke, the unequal expansion of bars of glass and zinc act on a lever and

register the height of the wet and dry bulb thermometers each five minutes upon a revolving cylinder. The direction, force and velocity of the wind are recorded as follows: The spindle of the vane carries a cam, against which rests one end of a bell-crank lever, whose other end traces the wind direction upon a moving sheet of paper. The pressure-plate having a surface of 1 sq. m. is attached to the vane and acts at right angles against a spiral spring whose tension is registered in kilos. upon paper placed below the direction sheet. The velocity is recorded on the same sheet by means of Robinson cups, which complete an electric circuit each time a kilometer of wind has passed. The rain and snow gauge, exposed on the flat roof, has a receiving surface of 4 sq. dcm. The rain runs into a cylinder suspended on a balance from the ceiling, so that the quantity can be read off from an index moving over a graduated one. Snow and hail remain on a strainer similarly suspended above the cylinder, and their total amounts are registered by an index. When melted, the resulting water passes into the cylinder, whence the total precipitation can be drawn off by a cock at the bottom. At night a continuous register is put in action, consisting of a drum turned by clockwork, against which a pencil attached to the cylinder bears. Another gauge is turned by a vane below it, and the water falls into a receptacle corresponding to the direction of the wind during the rain, accomplishing by somewhat different means the results obtained by the gauge at the Brussels Observatory. Evaporation from a freely exposed pan of water with a surface of 4 sq. dcm., balanced as in the rain gauge, is measured three times a day, the water added by precipitation being deducted.

The Olland tele-meteorograph was the first instrument which recorded at a central station the indications of instruments at a distant station. It was invented by Prof. Baumhauer in 1874, and a model constructed by Olland of Utrecht was exhibited at the Philadelphia Exposition of 1876, and another at Paris in 1878. In Utrecht an anemometer and barometer placed on the Cathedral tower, 103 m. above the ground, have for ten years recorded their indications at the Meteorological Institute, 2 km.

distant. The barometer is a mercurial one whose cistern is suspended from a balance which moves a needle to the right or left over an arc graduated in relief. On the axis of the needle is an arm provided with a platinum spring. Each quarter of an hour clockwork revolves the last-mentioned arm during which the spring moves over the graduations and the first needle. If these are connected with one pole of a battery whose other pole is connected with the arm, the current will be closed only when the spring touches a graduation or the needle. The current passes to the recorder where the style is carried by an electromagnet. The cylinder upon which this style registers turns once on its axis while the arm makes a revolution, so that at each contact a line is made on the lamp-blacked paper covering the cylinder. During the revolution of the cylinder a row of short equi-distant lines which represent the millimeter scale are traced, and between two or coinciding with one is another line resulting from the contact of the needle and spring, which represents the height of the barometer at that time. An advantage of the instrument is that the scale is marked and so cannot be displaced. The isochronism of the transmitter and recorder is assured by a conical pendulum which is liberated by clockwork each fifteen minutes. In the same way the indications of other instruments such as the Robinson anemometer, the wind vane and the Krecke thermometer, may be recorded and permanently "fixed" by dipping the paper in gum solution. The price of this instrument is 2,100 fl. ($860).

Measurements of atmospheric electricity were for twenty years made with a Peltier electrometer. A Mascart collector and the quadrant electrometer of Dr. Snellen are now used in connection with a photographic register placed in the cellar. In the same locality are the Lamont instruments for measuring magnetic variations in declination, horizontal and vertical intensity. For twenty years they were read directly, but for five years their indications have been automatically recorded by the Kew photographic apparatus. Each hour a clock operating a pneumatic shutter cuts off the light for a minute and a half in order to control the time. The instruments for absolute meas-

urements and some other variation instruments are located in a wooden pavilion in the garden. A set of the Lamont variation instruments which were read tri-daily for twenty years have been replaced by instruments of Dr. Snellen's design which are observed through a single telescope. The absolute declination and horizontal force are determined by a Lamont theodolite, made by Edelmann, four times a year from the mean of six observations. The absolute inclination is also determined four times a year by a dip circle of Dover and by a Weber galvanometer whose coil can be revolved vertically or horizontally in the plane of the meridian.

Weather Telegraphy.—Holland was one of the first countries to use the telegraph for the dissemination of weather information, and regular communications to the seaports began almost at the same time as the French. From June, 1860, barometric deviations from the normal were telegraphed to the seaports and made public by means of blackboards. The system differs from others in having the difference of the deviations of the barometer over a small extent of country as its basis. The observations used were those at Groningen, Helder, Flushing and Maastricht, situated at the four corners of Holland, which were telegraphed to Flushing, Utrecht, Amsterdam, Helder and Groningen, while the other ports only received them when the deviations in the north were 4 mm. smaller than in the south. Buys-Ballot was the first to carry out a system of storm signals on a government basis. Drums and cones corresponding to the English system were displayed at the ports in 1860, and when both systems were discarded in 1866 they were replaced at the Dutch ports by a semaphore apparatus called the aeroclinoscope. This is a mast with a pivoted cross-bar, which shows the direction and amount of the barometric gradient between the four Dutch stations. Originally the indications of the aeroclinoscope held for 24 hours, but soon the evening conditions were given and it was even proposed by Buys-Ballot to record continuously at the chief stations, by telegraphic communication, the barometric conditions at four other stations. In 1880 the form of the reports was altered so that all telegrams

now have the international form, and are received, worked up and distributed by the branch office in Amsterdam, through the distributing centres of Rotterdam and Groningen. The cost of the telegrams is paid by the government.

The Institute receives the 8 A. M. observation at 30 stations, including 6 Dutch, 6 Scandinavian, 3 English, 5 German, 10 Belgian and French stations. Observations at 12:30 P. M. come from the four domestic stations on the borders of the kingdom and one foreign station, and those at 7 P. M. from the same outlying Dutch stations. Utrecht also reports at 2 and 10 P. M. and Helder at 8 P. M. From the morning observations two charts are prepared, one having the isobars for each 5 mm.. the direction and force of the wind, the other the isotherms for each 5°C. and the pricipitation from 5 to 5 mm. A summary of the weather conditions as compared with the preceding day and predictions for the ensuing wind and weather are prepared. The charts are not published, but a few are drawn at Amsterdam and are posted there. By the side of this chart are shown the tabular weather reports of the morning, giving the barometric deviation from the normal yesterday and to-day, direction and force of wind, sky conditions, temperature yesterday and to-day, rainfall, state of sea and remarks, with the greatest barometic difference between the Dutch and European stations to-day and yesterday. These reports are copied in part by the press. Morning telegrams are sent in three groups of five figures each to 17 ports, at noon to 15, and in the evening to 8. The telegrams are deciphered and exhibited at the ports. The direction and amount of the barometric gradient between the four outlying Dutch stations is shown by the aeroclinoscope before mentioned, and at night a lantern is displayed when the indications are unfavorable.

The Stations, their Equipment and Observations.—There are six stations of the first order, viz., Utrecht, Helder, Flushing, Groningen, Maastricht and Amsterdam, which possess some recording apparatus, and three stations of the second order which observe pressure, temperature, precipitation, evaporation and cloud; 80 of the third order which observe precipitation,

weather and cloud; and about 350 thunder-storm observers. Of the latter there should be at least six in each district of 20 sq. km., but they are not evenly distributed. The observers are school-teachers, etc., and with the exception of the rain and thunder-storm observers are paid varying amounts. The stations are not often inspected, but the observations are checked by comparing them each month with the observations at the neighboring stations, and when a doubtful observation has been detected, inquiry is made and an inspection follows.

The barometer generally used is the closed cistern model with a reduced scale, made by Olland. The August psychrometer and Six maximum and minimum thermometer of German construction, are exposed outside a window protected by glass louvres and 1 to 3 m. above the ground. The rain-gauges are of zinc with a receiver of 4 sq. dcm., placed 1 m. above the ground. The water is measured in a glass graduate. A cylinder is added to the gauge for collecting snow, and if it is snowing at the time of observation another gauge is substituted while the snow is being weighed or measured. These gauges are made by Olland for 5 fl. (82). Evaporation is measured by atmometers of various patterns with surfaces of from 0.5 to 1 sq. m. screened from radiation. The anemometers give either the wind force or velocity, at other stations it is estimated on Beaufort's scale. The instruments are supplied by the Institute when the observers or institutions do not furnish them. The barometers are verified before and after erection, the thermometers before being sent out from Utrecht.

The hours for observations at the first and second order stations are 8 A. M., 2 and 8 or 10 P. M., and at the third order stations, 8 A. M. The maximum and minimum thermometers are read at 8 or 10 P. M., and the rain-gauges at 8 A. M. No special instructions have been issued except to the thunderstorm observers. The barometer is reduced to sea-level by a constant correction for each station, as no height above the sea amounts to 50 m. The tables of reduction are Guyot's. The schedules are supplied partly at the observers' expense and they have some liberty in the form. They are sent to the Central Office under

a government frank. The schedule for the first and second order stations is a single sheet with the days of the month grouped in decades in a vertical column, and these headings to the other columns:

Maximum and minimum temperatures.

Barometer in mm. reduced to 0° C.; morning, noon and evening.

Temperature in C° of dry and wet bulbs and difference; morning, noon and evening.

Vapor tension and humidity in mm.; morning, noon and evening.

Precipitation and evaporation in mm., measured in morning and evening and daily total.

Wind direction and force; morning, noon and evening.

Cloudiness; morning, noon and evening.

The monthly sums and means of these data are calculated. The time since 1885 is counted from midnight on the 24 hour system and fractions of hours are expressed in tenths. The schedule for the third order stations is a smaller sheet with the days divided into periods of five. The observations are:

Character of the weather during the preceding night to 8 A. M.

Cloudiness and amount of precipitation, measured at 8 A. M.

Character of the weather from 8 A. M to about 10 P. M.

Hydrometeors expressed in the international and other symbols with their hours of occurrence.

Remarks on plants and animals.

The thunderstorm schedules each contain the data for one storm with the parish and province in which it occurred and the time of occurrence, also the following questions to be answered: Was the storm far or near; when was the first thunder heard; when was the storm nearest; when was the last thunder heard; in what direction were the thunder and lightning; in what direction did the clouds move and with what velocity; what was the wind direction and force before, during and after the storm; when did the rain begin; how heavy was it; when did it end; when did hail begin, when did it end, and how heavy was it?

Was there damage by the storm? Another sheet to be filled out in case the latter occurred from lightning inquires the details of (1) the striking of persons or animals, and (2) of the striking of buildings, etc. Postcards have also been used for the thunder-storm reports.

The schedules of observations sent to Utrecht are checked, reduced and published. Before the Institute became a government institution in 1854 the publications were entitled *Meteorological Observations in the Netherlands.* Since 1854, the volumes are called *Dutch Meteorological Yearbooks*, and contain the tridaily observations at seven to ten stations, rain, phenological and other observations at 30–60 stations; further, the deviations of the pressure and temperature from the normals and a record of the meteorology of the year. The thunderstorm observations, begun in 1881, have been published in an annual volume until recently under the superintendence of Dr. Snellen, but the service is now directed by M. Engelenburg. This volume is presented to the coöperating observers, and it is the only recompense given. About 300 copies of the *Yearbook* are distributed free.

International Work.—Dr. Buys-Ballot has for many years endeavored to bring about a meteorological publication of an international character. For this purpose he has published in the second part of the *Yearbook* since 1865, data referring to the weather conditions over the whole of Europe, including also some important stations in other parts of the globe, such as detailed observations in Paramaribo, Nagasaki, Buenos Ayres, etc. The second parts of the *Yearbook* for 1866 to 1869, contain the deviations of the daily atmospheric pressure and temperature for the principal European stations, as well as a review of the rain and wind relations of the globe. The more recent volumes, 1870, 1871, 1872 and 1873, contain, besides, long series of temperature and pressure observations in Europe, as well as the corresponding means for the month and for each three days. Since 1876 the observations have been extended more and more over the Northern hemisphere. The *Yearbook* for 1879 gives the daily deviations for 150 stations.

MARITIME METEOROLOGY.

Holland was one of the first countries which carried out the programme adopted at the Brussels Maritime Conference of 1853, and sent its observations at sea to Lieut. Maury, in Washington. Upon the proposal of Buys-Ballot, an office for Dutch maritime meteorology was created, and the collection and working up of the observations made on the Dutch war and merchant ships was entrusted to it. The Amsterdam branch of the Meteorological Institute was established in 1881, and the Rotterdam branch in 1889.

Branch Offices—That at Amsterdam is situated on the Handelskade, in the vicinity of the docks. Here barometers, compasses and sextants belonging to sea captains are compared, English and other maritime charts corrected for their use, and work of a practical nature done. Weather bulletins and storm warnings are issued from this office, as has been before mentioned. The meteorological equipment of the station is of the first class and comprises an Olland meteorograph and the usual meteorological instruments for eye readings.

The Rotterdam office situated at Tryenvord, on the left bank of the river, is equipped similarly with magnetic and astronomical instruments, but does not yet possess a complete set of meteorological instruments.

Observations on Board Ship.—Sea captains who signify themselves ready to take regular observations receive from the Maritime branch of the Institute the following instruments, costing about 150 fl. ($60), viz.: 1 cistern barometer, 1 Naudet aneroid, 1 August psychrometer, 1 thermometer and two hydrometers with thermometers, also an extract-journal, or log-book, with instructions for entering the observations. Observations are collected from men of war and merchantmen, but hygrometrical observations are not required from the latter. The required data are the ship's position at noon, dead reckoning, direction of currents, barometer, wind, sea and air temperatures and weather. The two forms of extract-journals, the larger having 24 vertical columns for entering observations each two hours, and the smaller, 19 columns,

differ but slightly from the log-books of the London Meteorological Office, which has 26 columns. For the classification of the quality of the log-books received, the terms "excellent," "very good," "good" and "mediocre" are applied. The captains receive no remuneration except the publications of the Maritime department of the Institute, which also recommends the captains to the various societies which exist in Holland to promote navigation. Thus, a society in Rotterdam awards a silver medal for two good log-books, and a gold medal for six of them, and other societies in Amsterdam, Haarlem, etc., do the same.

Reduction of the Log-books.—After the log-books are checked and reduced they are treated as follows: Each journal is copied on schedules with the same headings as the original. One side only is ruled and each line has the number of the journal to be copied, in order later to correct errors which may be dicovered by reference to the original. It also has the place and date of observation. These sheets are cut into horizontal strips, so that each strip contains only the observations made in the same latitude and longitude. The strips which belong to the same 5° or 10° square are kept in envelopes and again classified so that those belonging to the same month are bound together. If there is enough material for a special investigation, the strips are again arranged according to time and place, and the mean values required for constructing charts are determined by laying the strips together. A more complete description of the method of collecting and reducing the observations will be found in *Suggestions on a Uniform System of Meteorological Observations* and the *Sequel to the Suggestions*, published by Buys-Ballot, in English, at Utrecht, in 1872 and 1873.

Since by far the greater part of the observations collected relate to routes to the East Indian colonies and the China Seas, special attention has been given to the meteorology of these regions. The first publications of the Maritime section were of a more general nature and are now out-of-date or have been replaced by later publications; the more recent ones relate to a single meteorological element only, such as wind, barometer, sea

temperature, etc., and differ thereby radically from the charts of the London Meteorological Office, upon which several elements are represented.

Following is a summary of some of the principal works published by the Maritime section of the Institute: *Investigation on Sea Temperatures and Currents, 1853, '61, '67, '72; Trade Wind Chart, 1856; Wind Chart of the N. Atlantic, 1856; General Wind Chart, 1860; Storm, rain, etc., Charts, 1862; Atlas and 4 Charts of the China Sea, 1863; Monthly Wind Charts of the N. Atlantic, 1877, '79; Sailing directions to and from Java, 1860, '68, '70; Mean Barometer around the Cape of Good Hope, 1874; Routes in China Seas and the Western part of the N. Pacific, 1879; Routes for Steamers between Aden and the Straits of Sunda 1871, '72, '81.* This department has also investigated the meteorology and typhoons of the China Seas, and has supplied the Deutsche Seewarte with data for the N. Atlantic, N. of 20°, in exchange for data required for its own investigations. At present the work in coöperation with the Deutsche Seewarte is upon the S. Atlantic and independently upon the Indian Ocean.

ANEMOMETER STUDIES.

By Professor C. F. Marvin.

In view of the discussion in *Science* and this Journal of results of anemometer experiments recently made in England and in this country, I desire to bring together certain points that have arisen in dispute and briefly present the various facts in a more connected form than has obtained in the previous discussions. We may in this way reach some final conclusion.

In the English experiments two distinct patterns of anemometer were used. One was the ordinary Robinson anemometer, the other was of recent design and designated the helicoid anemometer. In respect to the manner in which the wind operates to drive the latter of these anemometers it is, in general, very similar to the well-known Casella air meter and all the ordinary wind mills so common throughout the country. By means

of a tail or wind-vane attachment the instrument is made to present itself properly to the wind, which, in pressing against the inclined faces of the blades or sails, sets up, under these circumstances, the rotation. The pressure on each sail or blade, of which there are several, is effective in causing rotation. In the Robinson anemometer, on the other hand, the pressure on certain of the cups is to directly oppose the rotation, which, in this case, results from the difference of two pressures, and not from a direct pressure as in the former instrument. In the Robinson anemometer the pressure of the wind within the hollow concave surface of one set of hemispherical cups is opposed to that upon the rounded convex portion of an equal and opposite set of cups. It is important that these differences in the two kinds of anemometers be kept in mind while studying the results.

The experiments made in England were carried on in the open air with winds blowing at various velocities up to 4 miles per hour. The results obtained under these circumstances are very discordant for the Robinson anemometer and very uniform and satisfactory for the helicoid anemometer. The question is how shall we account for this? Some are inclined to attribute the irregularities almost entirely to the unreliable performance of the Robinson anemometer. This cannot be admitted unless the grossest neglects have obtained in its construction and use.

In the whirling machine experiments made by the Signal Office the greatest irregularity was found in the results when the whirler was set up in the War Department court, at which place it was found impossible to cut off all influence from natural wind movement, though the latter was very small. Afterwards, when the very same anemometers were tested in the Pension Office court, where the air was perfectly still, the results obtained were not only noticeably different from the former, but repeated determinations exhibited a remarkably close agreement. The results thus obtained prove conclusively that at ordinary velocities the greatest dependence can be placed upon the performance of the Robinson anemometer. It is observed further that the irregularities found in the English experiments and those made in the War Department court are, in some way, connected

with and attributable to the influence of the natural wind.

Professor Hazen in *Science*, and more fully in the May number of this JOURNAL, maintains that the ordinary influence of the natural wind, which influence is to slightly increase the relative velocity of the anemometer, is entirely sufficient to account for all the irregularities observed in the experiments. A close study of all the data, however, shows that this can hardly be true.

The influence of the prevailing wind, as referred to above, may be found as follows: When the anemometer, in addition to being moved on the whirler at a velocity V is also influenced by a natural wind movement of velocity W; the resultant velocity of the anemometer relative to the air is found to be

$$R = \sqrt{V^2 + W^2 - 2VW\cos.\theta}$$

where θ is the angle between the two directions of motion. The value of θ is continually changing as the whirler revolves, so that to find the mean value of the resultant for a whole revolution we must sum up all possible values and divide by the number. The above expression can be expanded into a series and the mean obtained by methods of calculus with the following result:

$$R = V\left\{1 + \frac{W^2}{4V^2} + \frac{W^4}{64V^4} + \text{etc.}\right\},$$

a series which will give R with sufficient accuracy when W is not too large in relation to V.

This enables us to calculate the effect of a prevailing wind in increasing the velocity of the anemometer relative to the air.

Professor Hazen shows (this JOURNAL, May, 1889, pp. 9 and 10) the resultant velocity of the anemometer, relative to the air, to be over 100 per cent. greater than the velocity of the whirler when the wind velocity is twice as great as that of the whirler, and when the two velocities are equal the mean resultant is 25 per cent. greater than either. When the velocity of the disturbing wind is one-half the velocity of the arm, the resultant is 6 per cent. greater than the latter, and, finally, a wind of velocity one-fourth that of the anemometer produces a resultant only 1.6 per cent. greater. Of course no importance whatever attaches to

the large increase in the first two cases cited, as no investigator would think of working under such conditions, nor can any conclusions be drawn from such facts. The last two cases giving a difference of 6 per cent. and 1.6 per cent., respectively, hardly sustain Professor Hazen's argument, as the discrepancies he wishes to account for are larger than 6 per cent., and the wind movement cannot be placed much larger than to correspond to the last of the above cases, and which requires a correction of only 1.6 per cent.

In order to account, by Professor Hazen's method, for the discrepancies shown by him in the English experiments (MET. JOURNAL, March, page 496), the wind in the meantime must have been blowing from 12 to 28 miles per hour, a condition of things entirely inadmissible. The velocity of the wind during the experiments is stated, by the committee, to have sometimes attained to four miles per hour. We cannot, therefore, attribute the discrepancies to the influence, as above understood, of the prevailing wind. Furthermore, even assuming that the wind actually was directly accountable, why are not the results with the helicoid anemometer similarly affected? Professor Hazen in his first paper, page 496, explains this by saying that the helicoid anemometer "was affected very slightly, if at all, by the free air currents which could operate upon it only at two portions of the whirl and where they practically balanced each other." It will be remembered the helicoid had a vane to keep it in the direction of the resultant wind. The above statement, therefore, is hardly consistent with the facts. In his second paper, page 11, he says: "The tendency of the vane would be to place itself normal to the arm, and before the free wind could overcome this the arm would move to another portion of the whirl where the wind would tend to move the vane in the opposite direction." This reasoning seems very faulty. The "tendency of the vane" would undoubtedly be to place itself in the direction of the *resultant wind.* This is its sole purpose, and though doubtless the mechanical action may have been somewhat imperfect on account of friction, yet, considering the general delicacy of the instrument as a whole, we cannot think

otherwise than that the vane followed quite closely the direction of the resultant wind, in which case, the helicoid, so far as being subject to the direct-wind influence, is circumstanced exactly as the Robinson anemometer; both experience equally the resultant of the two motions, viz., of the arm and of the prevailing wind, and since the results for the helicoid anemometer are quite regular we see no good reason for questioning the statement of the wind force committee, which gives four miles as the limiting velocity of the disturbing wind. Professor Hazen's table, and also the above formula, give the correction for such a wind at moderate and higher velocities of the whirler as one or two per cent. only, a quantity comparable with, or even smaller than, unavoidable errors of observation. In view of these facts we are compelled to reject the explanation offered by Professor Hazen as insufficient.

While engaged upon certain anemometer comparisons in the open air it occurred to me a plausible explanation of these discrepancies was to be found in the circumstance that the Robinson anemometer cups, of ordinary weight, when made to revolve on their own axis in still air will be brought to rest more quickly if the direction of rotation is such as to cause the concave sides to advance against the air than for rotation in the opposite direction. This fact is not only subject to, but is also the result of, direct experiment (MET. JOURNAL, April, page 562), and leads to the conclusion that if, for any reason, the cups in a steady wind have a velocity *greater* than that due to the wind, they will be retarded *less* rapidly than they will be accelerated when their velocity is less than that corresponding to the wind. Since the resultant velocity on a whirling machine operated in a wind is continually changing its value and varies between quite wide limits, it would follow that the mean velocity of the Robinson anemometer would be higher than would correspond to the mean resultant velocity. The details of this explanation are given in this JOURNAL for April, and in *Science* of March 29. Although developed independently by myself, it appears Professor Stokes was the first to consider this action and gave a formula (Proc. Roy. Soc., 1881, XXXII, page 174), in which the cor-

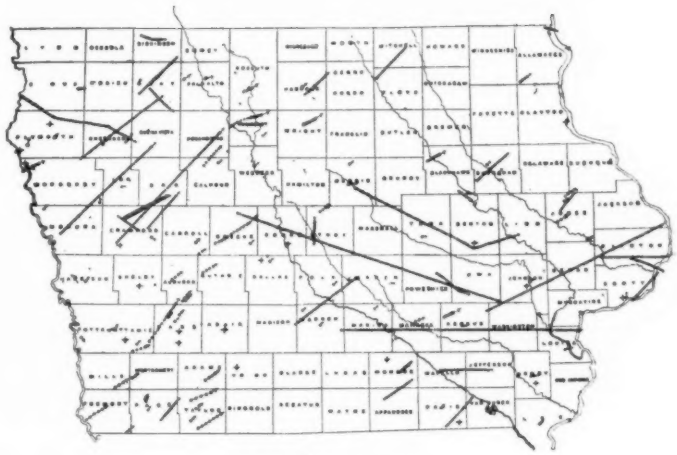
rection necessary with a Robinson anemometer of large moment of inertia and whirled in a natural wind, is three times as great as that determined by Professor Hazen or deduced from the above equation, and we might add, or that required by the helicoid anemometer.

Prof. Hazen credits the principle of this explanation with being "dangerously near the much sought after perpetual motion;" all that is needed is to lessen still more, in fact to remove entirely, the air resistance to the cups and other internal frictions and set the cups going. You will then have your perpetual motion. He also cited the case of the wind giving a momentary impulse to the cups and then ceasing entirely. This is exactly in support of the present explanation. Everyone familiar with anemometers knows how long the cups will continue to revolve after the impulse has ceased; every turn is registered on the dials as so much wind movement.

The crucial test to disprove Prof. Stokes' theory is pointed out to be the fact that in my own experiments the heavily weighted cups gave almost identical results with the lighter cups; that is, gave from two to six per cent. more wind. This is just as one might expect. Many of the fluctuations in the wind velocity are very sudden and recur at moderately short intervals, say of a minute or less. When the momentum of the cups is sufficient to carry them across this interval at nearly full speed, this is all that is needed. The experiments show that the cups as ordinarily made nearly satisfy this condition, so that increasing the moment of inertia two or three times was able to cause only a comparatively small gain after all.

It is admitted an easy matter to pick out a two minute velocity of remarkable peculiarity, but why is it possible to select hundreds of them that systematically indicate the same thing? Doubtless further experiments are needed before final results can be obtained, but it appears the momentum theory explains in a very satisfactory manner the greater part of the discrepancies found in experiments made in the open air, while that for which Prof. Hazen argues is evidently entirely insufficient. It is my intention to make a still further study of the agreement of different anemometers in the open air, but of late my attention has been so fully occupied with other important work that it has been impossible to give more than passing thoughts to the matter.

June 13, 1889.



TORNADOES IN IOWA.

STATE TORNADO CHARTS.—IOWA.

By LIEUT. JNO. P. FINLEY, Signal Service, U. S. A.

TABLE I.—*Tornadoes in Iowa.*

Period of observation, 52 years, 1837–1888.

Total number of storms, 128.

Year of greatest frequency, 1886,—26 storms.

Average yearly frequency,—7 storms.

Year in past (10) ten years no report of storms,—none.

Month of greatest frequency, June,—37 storms.

Day of greatest frequency, April 14th,—19 storms.

Hour of greatest frequency, 4 to 5 P. M.

Months without storms, January and December.

Prevailing direction of storm movement, NE.

Region of maximum storm frequency, central, southeast and western portions.

TABLE II.—*A Chronological Table, showing the location, date and time of occurrence, and general character of formation and movement of Tornadoes in the State of Iowa for a period of 52 years, from 1837 to 1888.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Henry	June 1.	1837	10 p. m.	E.	Funnel.	.....
Johnson and Cedar	June 7.	1843	5 p. m	E 20° N.	"	1,000.
Cedar and Clinton	June 5.	1844	4 p. m.	....	"	450.
Van Buren	"	1844	9 p. m.	SE.	.....	1,320.
Muscatine	"	1845	5 p m.	SE.	Funnel.	1,320.
Keokuk	July 8.	1845	....	L.	.....	100.
Henry	May 31.	1851	4 p. m.	E 15° N.	.....	225.
Scott	July 18.	1854	....	.....	....	....
Johnson	August 18.	1858	Afternoon.	NE.	.....	.....
Clinton	June 3.	1860	5 p. m.	NE.	Funnel.	800.
Page	June 14.	1866	4 p. m.	NE.	....	.....
Dickinson	June —.	1872	12 m.	SE.	Funnel.	....
Keokuk and Washington	May 22	1873	2:15 p. m.	E.	"	.. ..
Clayton	May 30.	1874	....	.....	.....	.....
Buchanan	July 26.	1874	....	....	.....	.....
Van Buren	February —.	1875	1 p. m.	.....	....	100
Van Buren	February 27.	1876	1:30 p. m.	N.	....	300.
Union	April 11.	1876	....	.....	....	....
Dubuque	May 18.	1876	Afternoon.	NE.	Inverted Funnel.	....
Harrison	July 4.	1876	....	NE.	.....	....
Lee	"	1876	Afternoon.	NE.	.....	.....
Shelby	May 18.	1877	7 p. m.	.....	.....	.....
Woodbury	May 30.	1877	.....	.....	.....	....
Appanoose	June 25.	1877	....	.....	....	.....
Pottawattamie	August 6.	1877	2:30 a. m.	SE.	....	....
Crawford and Sac	March —.	1878	....	NE.	Funnel.	....
Cass	April 18.	1878	Evening.	.....	....	.....
Wapello and Jefferson	April 21.	1878	3 p. m.	E.	Funnel.	1,320 to 2 640.
Monona and Buena Vista	"	1878	4 p. m.	NE.	"	600.
Crawford	"	1878	5:30 a. m.	SE.	"	660.
Crawford and Pocahontas	"	1878	4:30 p m.	NE.	"	990.
Crawford	April 23.	1878	Afternoon.	.....	.....	....
Jones	May 23.	1878	3:30 p. m	NE.	Funnel.	....
Adair	June 1.	1878	....	.....	....	....
Marion	June 15.	1878	....	NE.	.....	.....
Crawford and Sac	October —.	1878	.....	NE.	Funnel	.....
Tama	October 8.	1878	5 p. m.	E.	.....	1,320.

TABLE II.—*Continued.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Jones	October 8.	1878	5:30 p. m.	NE.	Inverted cone.	800 to 1,500.
Crawford, Carroll and Sac	October 15.	1878	Afternoon.	NE.	.....	.....
Page	May 30.	1879	2 p. m.	N.	Funnel.	100 to 3,000.
Plymouth	July 2.	1879	6:30 p. m.	NE.	Hour-glass.	.....
Davis	April 18.	1880	Afternoon.	NE.	Funnel.	150 to 900.
Warren	May —.	1880	.....	NE.	"	.....
Buchanan	May 25	1880	4:30 p. m.	NE.	.....	.....
Pottawattamie	June 9.	1880	Afternoon.	NE	Funnel.	.....
Cass	"	1880	.....	.....	.....	.....
Pottawattamie	June 10.	1880	Afternoon.	NE.	Funnel.	1,500 to 2,000.
Cass	June 29.	1880	6 p. m.	NE.	"	.....
Polk	October 15.	1880	4 p. m.	NE.	"	.....
Benton	May 13.	1881	.....	.....	"	.....
Pottawattamie	June 9.	1881	.....	.....	.....	300 to 2,640.
Jasper and Madison	June 11.	1881	4:15 p. m.	ENE.	Funnel.	150 to 660.
Hancock	"	1881	4 p. m.	NE.	.....	50 to 100.
Henry	June 12.	1881	.....	.....	Funnel.	.....
Warren	"	1881	4 p. m.	NE.	Funnel.	.....
Cherokee	June 28	1881	4 p. m.	NE.	"	.....
Calhoun	June 30.	1881	5 p. m.	NE.	"	.....
Dallas	July 7.	1881	Afternoon.	NE.	.....	.....
Clay	August 5.	1881	4 p. m.	NE.	.....	1,200 to 1,500.
Allamakee	September 26.	1881	4:35 p. m.	.....	.....	2,640.
Hardin	September 29.	1881	Afternoon.	NE.	.....	.....
Van Buren	April 6.	1882	1:30 a. m.	NE.	.....	300 to 1,320.
Story	April 8.	1882	.....	NE	.....	300.
Poweshiek	June 17.	1882	8:45 p. m.	E 20° S.	Funnel.	450 to 600.
Boone	"	1882	7 p. m.	NE.	"	1,050.
Clay	June 21.	1882	6:30 a. m.	SE.	.....	2,640.
Buchanan	June 22.	1882	5:27 p. m.	NE.	.....	5,280.
Sioux	June 24.	1882	6 a. m.	E.	.....	.....
Dallas	"	1882	About 5 a. m.	.....	.....	.....
Floyd and Mitchell	July 17.	1882	5:30 p. m.	NE.	Funnel.	.....
Scott	October 30.	1882	3:30 p. m.	NE.	.....	1,320.
Greene	November 10.	1882	Evening.	NE.	.....	.....
Woodbury	April 21.	1883	6:30 p. m.	N.	Funnel.	.....
Webster	April 26.	1884	8 p. m.	NE.	Inverted cone.	.....
Scott	May 5.	1884	5 p. m.	.....	Inverted cone.	300.
Humboldt	June 18.	1884	1:15 p. m.	NE.	Acorn.	.....

TABLE II.—*Continued.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Hardin	July 4.	1884	6 p. m.	E.	Funnel.	70.
Crawford	"	1884	7 p. m.	SE.	.....	.....
Sioux, Plymouth and Cherokee	"	1884	5 p. m.	SE.	Funnel.	.....
Harding, Benton and Linn	"	1884	6 p. m.	SE.	"	.....
Woodbury	"	1884	4:40 p. m.	E 10° S.	"	.....
Poweshiek and Iowa	July 23.	1884	9 p. m.	E 10° S.	"	660 to 2,640.
Mahaska	"	1884	5 p. m.	.....	"	.....
Woodbury	September 9.	1884	Evening.	NNE.	"	200 to 300.
Ida	June 12.	1885	10:50 p. m.	E.	"	990.
Davis	"	1885	5:30 p. m.	.....	.....	.....
Jasper	"	1885	3 p. m.	E.	Funnel.	.....
Cass	"	1885	.....	.....	.....	.....
Woodbury	"	1885	6:48 p. m.	.....	.....	.....
Woodbury	"	1885	6:30 p. m.	NE.	.....	.....
Cherokee	June 14.	1885	11:30 p. m.	NE.	.....	.....
Cherokee	"	1885	Night.	NE.	Funnel.	.....
Cherokee	July 30.	1885	5:50 p. m.	.....	"	.....
Louisa	November 6.	1885	.....	ENE.	.....	.....
Carroll	April 14.	1886	5:05 p. m.	NNE.	Funnel.	165.
Cass and Audubon	"	1886	4 p. m.	NNE.	"	1,320.
Taylor	"	1886	8:30 p. m.	NNE.	"	150.
Fremont	"	1886	4 p. m	NE.	"	2,640.
Story	"	1886	5:10 p. m.	N 30° E.	"	About 60.
Taylor	"	1886	Afternoon.	NE.	"	300 to 500.
Taylor	"	1886	8 p. m.	NE.	"	260.
Mills	"	1886	5 p. m.	NE.	"	150 to 300.
Calhoun	"	1886	3:35 p. m.	NE.	"	20 to 75.
Audubon	"	1886	4:20 p. m.	N 45° E.	"	60 to 320.
Audubon	"	1886	4:20 p. m.	N 10° E.	"	80 to 1,650.
Cass	"	1886	4 p. m.	NE.	"	100 to 350
Taylor	"	1886	8:30 p. m.	N 40° E.	"	1,320.
Carroll	"	1886	5 p. m.	NE.	"	.....
Pottawattamie	"	1886	5 p. m.	NE.	"	300.
Guthrie	"	1886	4:40 p. m.	N 30° E.	"	40 to 600.
Fremont	"	1886	6 p. m.	NE.	"	.....
Adams	"	1886	8:30 p. m.	N 23° E.	"	1,320.
Montgomery	"	1886	3 p. m.	NE.	"	.....
Jones	May 8.	1886	10 p. m.	ENE.	"	.....

TABLE II.—*Concluded.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Jones	May 8.	1886	11:30 p. m.	.....	.....	.....
Jones	May 8.	1886	10 p. m.	NE.	Funnel.	.....
Mahaska	May 9.	1886	1 p. m.	NE.	.....	.....
Monroe	May 9.	1886	1 p. m.	NE.	.....	.....
Keokuk	May 9.	1886	3:15 p. m.	Easterly.	"Waterspout."	.....
Audubon	May 14.	1886	Afternoon.	NE.	Funnel.	150 to 450.
Humboldt	August 8.	1887	7 p. m.	NE.	"	Narrow.
Greene	August 10	1887	Evening.	NE.	"	Narrow.
Woodbury	April 5.	1888	Afternoon.	NE.	"	Narrow.
Kossuth	July 4.	1888	2 p. m.	NE.	"	650.
Palo Alto	"	1888	3 p. m.	NE.	"	3,000.
Palo Alto	"	1888	Afternoon.	NE.	"	Narrow.
Wright	"	1888	3 p. m.	NE.	"	2,500.
Keokuk	"	1888	2 p. m.	NE.	"	1,800.
Black Hawk	"	1888	Evening.	NE.	"	350.
Black Hawk and Benton	November 1.	1888	8 p. m.	ESE.	Globular.	300 to 900.

TABLE III.—*Relative frequency of Tornadoes by months and days, for Iowa.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
January		0	0
February	27 and (—)	2	2
March	(—)	1	1
April	5, 6, 8, 11, (14)^{2}, (18)^{2}, (21)^{2}, and 26	8	32
May	5, (8)^{2}, (9)^{2}, 13, 14, (18)^{2}, 22, 23, 25, (30)^{2}, and 31	11	18
June	(1)^{2}, 3, (5)^{2}, 7, (9)^{2}, 10, (11)^{2}, (12)^{2}, (14)^{2}, 15, (17)^{2}, 18, 21, 22, (24)^{2}, 25, 28, 29, 30, and (—)	20	37
July	2, (4)^{13}, 7, 8, 17, 18, 23, 26, and 30	9	21
August	5, 6, 8, 10, 18	5	5
September	9, 26, and 29	3	3
October	(8)^{2}, (15)^{2}, 30, and (—)	4	6
November	1, 6, and 10	3	3
December		0	0
Total		66	128

NOTE.—The blank (—) signifies date missing.

CURRENT NOTES.

THE METEOROLOGICAL OBSERVATORY OF THE MADGEBURG ZEITUNG.—The seventh year-book of this noteworthy enterprise is for 1888, and appeared early in the year. An account of the enterprise was given in the early volumes of this JOURNAL. There has been little change in the interval except the change in director from Dr. Assmann to Herr Grützmacher and the improvement in details which always follow in an important undertaking earnestly carried on, as is the case with this.

THE REPORT OF THE KANSAS STATE BOARD OF AGRICULTURE for the quarter ending March 31, 1889, is chiefly occupied by an illustrated paper on the native grasses of Kansas, by Prof. W. A. Kellerman, and short articles on the irrigation question, by Prof. G. E. Curtis and others. There are also reports of correspondents on the condition of crops, fruit, live stock, etc., and the bulletin of the Kansas Weather Service, which is directed by Prof. J. T. Lovewell, assisted by Sergeant Jennings of the Signal Corps. In the verification of the Government indications for March we note that five stations report 100 per cent. verified for weather and three stations do the same for temperature. When it is considered that a failure on one day would lower the percentage by more than three per cent., it is evident that the verifications are not trustworthy. The percentage of cold waves verified is put at 81 per cent., but it is probable that the number of cold waves for which no warnings were given has not been included in the estimate, since the official verifications of cold wave warnings in March throughout the whole country is only 62 per cent. A. L. R.

THE SIXTEENTH ANNUAL REPORT of the Secretary of the Michigan State Board of Health has recently been issued. It contains detailed tables of the meteorological conditions in Michigan during 1887, compiled from the reports of observers for the State Board of Health and for the United States Signal

Service, and the data are also plotted graphically. The table showing the hourly velocity of the wind for each month and the year at Lansing is valuable because so few data have been published in the United States concerning the diurnal period of the wind. It is stated that the anemometer used at the stations was Robinson's, except Gibbon's at Ann Arbor. As a matter of fact, all the anemometers with four hemispherical cups are of the Robinson pattern, and the electrical recording apparatus used by the Signal Service is that of Gibbon. It is of much greater importance to know the exposure of the various instruments, since anemometers differently placed in the same town show great differences in the amount of wind recorded.

The ozone observations, which have been conducted for ten years, are interesting, though we do not think that the method of testing it by Schönbein's paper is satisfactory. The quantity of air passing over the paper and the moisture of the paper itself affect greatly its discoloration, and these conditions are influenced by its exposure, though we can hardly suppose the composition of the air varies within these limits. The amount of ozone at night, in Michigan, is seen to be greater than during the day, notwithstanding the decrease in wind velocity at night, but it is possible that the increased humidity then, rendering the test paper more sensitive, more than counteracts this circumstance.

The remainder of the volume is occupied with interesting investigations by Dr. Henry B. Baker on the time of greatest prevalence of each disease in 1887 and on the relations of certain meteorological conditions to the diseases of the lungs and air passages and by reports on contagious diseases, etc., There is a copious index to the 277 pages. A. L. R.

THE SPECTRE OF THE BROCKEN.—A writer in *Ciel et Terre* discusses the phenomenon of gigantic shadows of persons seen on the clouds around a mountain, and shows that the theory that the sun could form a magnified image as well as a candle is incorrect. The sun's distance is only about one hundred times its diameter, consequently the rays emanating from the edges

of the sun and passing on each side of the observer meet at a distance beyond him equal to one hundred times the size of his body, or at about 157 feet. At this distance there will be no real shadow but a penumbra twice as large as the body and increasing at the sides. At any distance less than 157 feet there will be an umbra and a penumbra, the umbra increasing and the penumbra decreasing as the man is approached. Beyond 157 feet the penumbra will be larger and lighter, becoming more indistinct as it recedes. In this calculation the question of diffraction has not been considered. From some experiments made by the author, a human shadow on the ground, showing the legs and arms distinctly, could not be seen beyond 56 feet, and a good shadow of an alpenstock could not be formed beyond 26 feet. These distances may vary a little according to the brilliancy of the sun and the nature of the ground on which the shadow is cast. There is no definite line of demarkation between the umbra and penumbra, and it is impossible to say where one begins and the other ends, and it is even difficult to fit the limits of the penumbra.

All the pictures which have been published of men and their spectres are purely fanciful. Two men may be able to see their respective spectres if they are standing very near one another, but no one, so far as the writer's knowledge goes, has seen a man and his spectre at a sufficient distance to sketch them. Having shown that a shadow larger than nature is impossible, and that a distinct shadow cannot be formed at the distances alleged, the enormous size of the shadows which figure in the descriptions are explained as the result of an error in the estimation of the distance. The observer thinks that the shadow is very large and very far away whilst it is very near and of natural size. In the majority of these cases, each observer sees only his own shadow and not those of his companions.

A shadow on fog is not like a shadow on a wall; a part of the shadow is thrown upon particles of water situated at a certain distance and other parts on particles at other distances. Consequently, the shadow can only be seen by a person who looks at it from the spot where the person is whom it reproduces. If

the shadow was really a long distance off there would be no difficulty in another person seeing it, provided he was a short distance from him who made it. In many cases the shadows of the arms can only be seen when they are moved. This may be explained by supposing that the shadows of the arms in motion are thrown on a nearer cloud than that on which the remainder of the shadow was seen, this being too faint to be seen at rest. Being nearer, this shadow appeared gigantic.

This explication of the apparently enormous size of the shadow was given by Professor Lommel in *Wind und Wetter*, in 1873, but he does not claim it as original.

As sustaining the theory stated above, the following account of the phenomenon as seen from Pike's Peak in 1878, by so accurate an observer as Prof. S. P. Langley, is quoted from his "New Astronomy": "Directly opposite the setting sun and on the mist over the gulf beyond us, was a bright ring, in whose centre were three phantom images of our three selves, which moved as we moved, and then faded as the sun sank. These ghostly presentiments were tolerably defined but did not seem to be gigantic, as some have described them. We thought them close at hand but before we could determine, the vision faded." A. L. R.

A METEOROLOGIST ON HIS TRAVELS.*—The title of this note expresses the exact purpose of this book, and when we add that the meteorologist in question is a thoroughly competent one, that the book is excellent from a purely book-making point of view, clear and interesting in style and typographically attractive, our readers will see that it is worth possessing. The author has visited the most of the latitudes between the Arctic and Antarctic circles, and has everywhere found something interesting to tell; generally these interesting matters are meteorological, but sometimes they relate to other things. In every case he has successfully escaped the *banale*, typeworn commonplaces of the ordinary books of travel nowadays. For further information we

*Seas and Skies in many Latitudes, or Wanderings in Search of Weather, by the Hon. Ralph Abercromby, F. R. Met. S. London: Edward Stanford, 1888. Octavo, 447 pages, with maps and many illustrations.

must refer our readers to his pages themselves,—only remarking that the author preserves in this book a characteristic which is marked in his "Weather," and that is suggestiveness. It is noteworthy, for instance, how much of novelty he finds in his two visits to the States, to suggest to some of us who have spent the most of our lives in them. We are glad to see that he parts with us with some words of hearty commendation for the Signal Service.

THE BIBLIOGRAPHY OF TEMPERATURE.*—This copy of the type-writer sheets of the bibliography of temperature is of very great interest, both for itself and for the promise it gives of our eventually having a full bibliography of meteorology. That such a bibliography is needed may be seen from the fact that this volume contains about 2,000 authors and 8,000 titles. This is only for temperature; the entire number of titles now is 56,000.

The general classification to be employed in the full work is as follows: The three general divisions are General, Theoretical, and Applied Meteorology and Observations. Under the first division the subdivisions are history and bibliography, general and collective works, organization and method, and instruments, the latter with eight subheads. Under theoretical meteorology are physics of the atmosphere (including temperature, moisture, pressure, optical phenomena, and electrical phenomena), mechanics of the atmosphere (including general circulation, winds, and storms), and cosmic relations of meteorology (influence of the moon, planets, and sun spots, and phenomena attending eclipses). Applied meteorology is subdivided into weather predictions, agricultural meteorology, medical meteorology, and climatology. The observations are to be arranged geographically.

The present part (temperature), which is a subhead of a subdivision, is further subdivided into temperature in general, solar

* The Bibliography of Meteorology, a classed catalogue of the printed literature of meteorology, from the origin of printing to the close of 1881; with a supplement to the close of 1887, and an author index. Prepared under the direction of Brig. Gen. A. W. Greely, Chief Signal Officer U. S. Army; edited by Oliver L. Fassig, Bibliographer and Librarian, Signal Office. Part I, Temperature. Washington: Signal Office, 1889. Lithographic reproduction of type-written copy; quarto: 381 pages.

radiation, terrestrial radiation, periodic variations, non-periodic variations (with six subdivisions), vertical distribution, horizontal distribution, temperature of earth, temperature of ocean, temperature of lakes and rivers, temperature of springs, ground-ice, calculation of mean temperature, and temperature of space. The references are arranged chronologically under each one of these heads, and the 325 pages filled by them are followed by the 55 pages of an index of authors.

The work has been done by Mr. C. J. Sawyer, assisted by Mr. O. L. Fassig and Mr. H. E. Hilton. Mr. Sawyer resigned in 1887, and Mr. Fassig was then made librarian in his place. The card catalogues of Mr. G. J. Symons, of London (18,000 titles), and of Professor Abbe (11,000 titles), were employed, and the aid of many eminent and interested gentleman scattered over the earth's surface was freely given. The work seems to be accurately done and quite exhaustive, at least up to 1881. In its present form it is probably intended only for temporary use. It is to be hoped that Congress will authorize the publication of the entire bibliography. It would be a great boon to the science to which it relates.

A New Form of Self-Registering Soil Thermometer.—Prof. Milton Whitney, professor of agriculture and vice-director of the experiment station of the University of South Carolina, has devised a modification of Six's thermometer for soil temperature. The bulb is six inches long, protected by a metallic cylinder perforated with many holes, and is buried in the soil so that it shall extend from three to nine inches below the surface of the soil; the maximum and minimum scale being of course above the soil and arranged very much as in the ordinary Six's form. The long bulb allows of a good height of scale, while it is narrow enough to respond readily to changes of temperature. In a series of readings the instrument gives exactly the mean of the readings of a three, six, and nine-inch thermometer of the usual form, placed beside it at these respective depths in the soil, besides recording the maximum and minimum temperature. This height of bulb and depth in the soil was decided

on, as it is supposed to be the depth which contains most of the roots of the ordinary cultivated plants. The instrument need only be read once a day, besides saving an immense amount of calculation and tabulation attending the tri-daily readings of the six to eight instruments comprising the sets of the usual form. The cost is very much less ($10) and from its simplicity and compactness and little attention needed, it is well adapted for distribution over a State to stations coöperating with the Signal Service, or to place in the hands of other competent and interested persons, to be placed in soils of different character from the home station. Several instruments have been made for the South Carolina experiment station by H. J. Green of New York, and they are giving great satisfaction. There is some risk in transportation, as the index is liable to become imbedded in the mercury, which necessitates sending the instrument in an upright position in a box fitted with gimbals.

Diurnal Oscillation of the Barometer.*—In this memori Dr. Hann proposes to himself the inquiry: If the diurnal oscillation of the barometer is due to the solar radiation, should there not be a yearly variation in its amount with a maximum at perihelion and a minimum at aphelion? As the solar radiation is one fifteenth greater at perihelion than at aphelion, it seemed probable that such a variation should be found. Harmonic analysis with numerical computations, not graphic, was employed in the study of over one hundred records of hourly observations. The formula assumed a daily, a bi-daily and a tri-daily tide, and the results gave not only a reply to the inquiry with which Dr. Hann started out, but also afforded a crowd of other interesting facts, some of which were unexpected.

The answer to Dr. Hann's inquiry was in the affirmative and the quantitative annual change in the amplitude of the bi-daily tide was greater than was required by theory. Besides, a remarkable uniformity of phase was found in this tide; the amplitudes also decrease with elevation above the sea about in

*Untersuchungen über die tägliche Oscillation des Barometers von Dr. J. Hann. W. M. K. Akad., besonders abgedruckt as dem LV. Bande der Denkschriften der Math.—Naturw. Classe der Kaiserlichen Akademie der Wissenschaften, Wien, 1889. Quarto. 73 pages.

the ratio of the air pressure; and they also decrease with latitude, disappearing near the arctic circle. Besides the annual change in amplitude, coincident with the earth's position in her orbit, there was a larger biennial period with maxima at the equinoxes.

The diurnal tide is very variable in phase and in amplitude and seems, totally unlike the bi-daily tide, to be much dependent on local conditions. For instance, the amplitude is much increased in mountain valleys. The tri-daily tide, hitherto unsuspected, and apparently put in his formula by Dr. Hann simply to complete it and take up casual numerical variations, comes out very small in amplitude but surprisingly uniform in phase, and has in addition an astonishingly uniform annual period with a maximum near the winter solstice and a minimum near the summer one. Dr. Hann therefore concludes that the tri-daily element is not illusory, but an essential constituent of the diurnal oscillation of the barometer.

Relation of Rain-Areas to Areas of High and Low Pressure.—Professor Loomis's twenty-third paper, of his series of Contributions to Meteorology, published in the *American Journal of Science*, relates to rain-areas. The treatment is statistical: the statements are so condensed that only a republication of the entire paper could convey to our readers a just idea of its value. Lack of space prevents this, and we will reproduce only some general conclusions in the words of the author himself.

The conditions favorable to rain-fall are:

A. One of the most common causes of rain is an unstable condition of the atmosphere resulting from an unusually high temperature combined with unusual humidity. This condition of the atmosphere is most frequently found where the barometric pressure is somewhat below the mean, although it sometimes extends beyond the isobar of 30 inches. It is most frequently found in the eastern segment of the low area, and is generally accompanied by easterly or southerly winds.

B. Another very common cause of rain, and one which is frequently associated with the former, is a cold northerly or westerly wind in the western segment of the low area. This cold wind pushes under the warm and humid wind which prevails in the eastern segment of the low

area, and lifts it up from the earth's surface to such a height, that a considerable portion of its vapor is condensed. Frequently there is direct evidence that the westerly winds in the rear of a storm are merely surface winds, and that the southeast winds which prevailed in front of the storm extended to the rear, occupying a stratum of considerable elevation. It is generally difficult to obtain evidence of the direction of the upper stratum of air, while a rain-storm is prevailing at the surface of the earth; but occasionally there are breaks in the lower stratum of clouds which enable us to observe the movement of the upper clouds. The observations on Mount Washington afford us at all times the means of comparing the winds at low stations with the winds at the height of 6,000 feet. We frequently find that the latter winds are from the south or southeast, while the surface winds are from the north or west.

C. Proximity to the ocean or to a large inland sea is favorable to rain-fall. We have seen that heavy rains are more frequent near the coast of the Atlantic Ocean and Gulf of Mexico, than they are at interior stations.

The following facts seem well established:

D. No great barometric depression with steep gradients ever occurs without considerable rain. This is true not only for the United States, but also for the cyclones of the West Indies, for those of the China Sea, of India and the Bay of Bengal.

E. In great rain-storms the barometric pressure generally diminishes, while the rain-fall increases.

F. The greatest depression of the barometer generally occurs about twelve hours after the greatest rain-fall.

G. A great fall of rain is favorable to a rapid progress of the center of least pressure, while a small rain-fall is generally attended by a less rapid progress. It is, however, plain that the rate of progress of a low center depends partly upon other causes than the amount of rain-fall.

Of areas of low pressure, the author says:

If areas of low pressure of great geographical extent may be formed and maintained for several days with very little rain, is there no difference between the low areas which are attended by a heavy rain-fall, and those which are attended by very little rain? Differences do exist, and generally they are strongly marked. The following are some of them:

Characteristics of Areas of Low Pressure.

With excessive rain-fall.	With little or no rain.
a. Steep barometric gradients.	*a.* Feeble barometric gradients.
b. Violent winds.	*b.* Moderate winds.
c. Rapid changes of barometric pressure.	*c.* Slow changes of barometric pressure.
d. Rapid progressive movement.	*d.* Slow progressive movement.

These are the characteristics of an area of low pressure which stands alone, uninfluenced by the proximity of a second area of low pressure.

When two areas of low pressure are formed near each other, their movements are often very complicated.

Concerning geographical relations, he says:

A comparison of the results now obtained suggests some important conclusions respecting the influence of local causes in modifying the relation of rain-fall to barometric pressure. We have found that in the United States, east of the Rocky Mountains,—

1. South of Lat. 36°, a rain-fall of 2½ inches in 8 hours at any station occurs on the east side of a low area more frequently than on the west side, in the ratio of 2·6 to 1.

2. North of Lat. 36°, a rain-fall of 2 inches in 8 hours at any station occurs on the east side of a low area more frequently than on the west side, in the ratio of 2·8 to 1.

3. A total rain-fall of 9 inches in 8 hours at all the stations east of the Rocky Mountains occurs on the east side of a low area more frequently than on the west side, in the ratio of 6·2 to 1.

4. Over the North Atlantic Ocean great rain-areas occur on the east side of an area of low pressure more frequently than on the west side, in the ratio of 2·6 to 1.

5. In Europe a rain-fall of 2½ inches in 24 hours at any station occurs on the east side of a low area more frequently than on the west side, in the ratio of 2·0 to 1.

These results indicate that in the United States and Europe, as well as over the North Atlantic Ocean, great rain-falls are generally associated with a barometric pressure somewhat below the mean, and the precipitation occurs chiefly on the eastern side of a low area.

Finally,

By grouping together those stations which seem most intimately related, we obtain the following results, showing the ratio of the amount of precipitation which comes with a falling barometer, compared with that which comes with a rising barometer.

Indianapolis, Ind.,	ratio,	1·32 to 1
Philadelphia, Penn.,	"	2·88 to 1
Seven British stations,	"	2·08 to 1
Paris and Brussels,	"	1·19 to 1
Pawlowsk, Russia,	"	1·06 to 1
Prague and Vienna,	"	0·80 to 1

ROYAL METEOROLOGICAL SOCIETY.—The usual monthly meeting of this Society was held on Wednesday evening, the 20th of March, at the Institution of Civil Engineers; Dr. W. Marcet, F R. S., President, in the chair.

Mr. A. J. Hands, F. S. A., Mr. J. Jackson, Mr. S. A. Jones,

Mr. J. E. Middlehurst, and Mr. L. Sutton, F. R. G. S., were elected Fellows of the Society.

Dr. Marcet delivered an address on "The Sun, its Heat and Light," in which he said that the source or origin of all meteorological phenomena is the sun, which sends or radiates its heat to the earth through the molecular vibration of the invisible matter connecting earth with space. If there were no air and moisture we should feel the sun's heat to a much greater extent. After the sun's rays have reached the earth, a portion of the heat they bring with them is absorbed by the earth and terrestrial objects, another is converted into motion, and a third is reflected into space. After describing the various actinometers and other instruments used for determining the amount of solar radiation, Dr. Marcet showed that the temperature of the solar rays falls rapidly when tested at increasing altitudes in a balloon. He then gave an account of some observations made by Mr. Glaisher, in the celebrated balloon, Ascent, which he and Mr. Coxwell made from Wolverhampton on September 5th, 1862, when they reached a height of about seven miles above the earth's surface. Regarding the transformation of solar heat into motion, a very interesting illustration is afforded by the radiometer, in which the direct influence of the sun's rays causes a light vane to rotate, while another illustration of the mechanical effects of heat upon fluids, is their conversion into what is known as the spherical condition. In connection with this Dr. Marcet showed how by wetting his hand he could pass it through molten lead without injury. He also related the case of Henry Hall, one of the keepers of the Eddystone Lighthouse, who, on the occasion of the fire which destroyed the lighthouse, on December 4th, 1755, accidentally swallowed some molten lead, but did not die till several days afterwards, when a piece of lead was taken out of his stomach. Dr. Marcet then briefly drew attention to the sun's light, stating that the passage of the sun's light through our atmosphere alters it in kind to a great and remarkable extent. Light can be composed into its elementary colors. In connection with this branch of the subject, Dr. Marcet performed a number of experiments, including among

others, that of passing a ray of light through a glass vessel freed from dust, when the ray disappears within the vessel, but reappears on the other side, showing that the power to form light was there, though not the material for this power to act upon. Dr. Marcet concluded his very interesting address by describing the various forms of sunshine recorders.

The meeting was then adjourned in order to afford the Fellows and their friends an opportunity of inspecting the Exhibition of Instruments opened on the previous evening.

The exhibition was devoted principally to actinometers and solar radiation apparatus, and also included sunshine recorders, several new instruments and a number of interesting photographs of meteorological phenomena.

Among the instruments shown for ascertaining the absolute heating effect of the sun's rays, were, Herschel's, Hodgkinson's and Stewart's actinometers, Pouillet's and Angström's pyrheliometers, and Secchi's solar intensity apparatus. There were also Luvini's dietheroscope for observing the changes of atmospheric refraction optically; Bellami's lucimeter as used in Italy, and Crookes's radiometer, in which the arms rotate with more or less velocity under the action of radiation.

All the various patterns of solar radiation thermometers were exhibited, from the plain black-glass bulb maximum to Richard's continuously-recording black-bulb and bright-bulb thermometers *in vacuo*.

An interesting collection of sunshine recorders was also exhibited, among which were the Campbell-Stokes and Whipple-Casella burning recorders, and the Jordan and McLeod photographic recorders.

Several new barometers, anemometers, nephoscopes, etc., were also shown, as well as the stephanome, which is used for measuring the angular size of halos, fog-bows, and glories at the Ben Nevis Observatory.

Mr. Clayden showed an ingenious working model of the Atlantic Ocean, illustrating the formation of ocean currents in general and of the Gulf Stream in particular. Some models of very large hailstones, 7 inches in circumference, which fell near

Montereau, France, on August 15th last, were also exhibited.

The exhibition included a very interesting collection of photographs of flashes of lightning, and also a number of photographs of clouds taken in various parts of the world, and views taken on the summit of Ben Nevis.

The exhibition remained open till Friday.

The usual monthly meeting of this Society was held on Wednesday evening, the 17th of April, at the Institution of Civil Engineers, 25 Great George Street, Westminster; Dr. W. Marcet, F. R. S., President, in the chair.

Mr. R. C. Mossman and Mr. E. H. Ryan-Tenson, M. R. C. S., were elected Fellows of the Society.

The following papers were read:

1. "On the Deaths caused by Lightning in England and Wales from 1852 to 1880, as recorded in the returns of the Registrar-General," by Inspector General R. Lawson, LL. D. The total number of deaths from lightning during the 29 years amounted to 546, of which 442 were of males, and 104 of females. In consequence of their greater exposure, the inhabitants of rural districts suffer more from lightning than those of towns. It appears also that vicinity to the west and south coasts reduces the chances of injury by lightning, and that distance from the coast and high land seems to increase them.

2. "The diurnal range of the Barometer in Great Britain and Ireland," by Mr. F. C. Bayard, F. R. Met. Soc. The author has reduced the hourly records of the barometer at the nine observatories, Aberdeen, Armagh, Bidston, Talmouth, Glasgow, Greenwich, Kew, Stonyhurst, and Valencia, during the years 1876–1880. The curves of inland places are smoother than those of places on the sea-coast, and the curves of places to the westward are more irregular than those of places to the eastward. As we go from south to north the general tendency of the curve is to get flatter with a lessened diurnal range.

3. "Note on a Working Model of the Gulf Stream," by Mr. A. W. Clayden, M. A., F. R. Met. Soc. The author showed this interesting model at work; it has been constructed to illustrate the formation of ocean currents in general and of the Gulf Stream in particular.

4. "On the Rime-frost of January 6th and 7th, 1889," by Mr. C. B. Plowright, F. L. S. The author gives an account of the very heavy rime which occurred in the neighborhood of King's Lynn on these days, when the fringe of crystals upon twigs and branches of trees was about two inches in length. The weight was so great that nearly all the telegraph wires were snapped and an immense number of branches of trees broken off.

THE INTERNATIONAL METEOROLOGICAL COMMITTEE. — The fourth (and last) meeting of this committee was held at Zurich, in September, 1888. This is the last meeting of the committee: it is now dissolved, and its place is to be taken by a conference of the heads of meteorological services.

From the published report of this meeting of the committee we clip the following matters of interest to our readers. On the matter of the classification of clouds it was decided that:

"The Committee considers that it cannot at present recommend the general adoption of the proposal of MM. Hildebrandsson and Abercromby, but it recommends meteorologists to continue their study of this question in order to obtain representations, both photographically and also in colors, such as might be introduced generally in Meteorological Instructions."

As to the conditions to be recommended for the observations from distant stations, the committee warmly supported Dr. Hann's proposal, which was as follows:

M. Hann was of opinion that, as a considerable number of reports relating both to meteorology and climatology, were published by travellers and geographers, it would be well to lay down rules for publishing the results, especially if they were to be utilised for scientific researches.

1. It should be stated what kind of instruments had been used for the observations, their corrections should be given, if known, as well as details as to the method of exposure. The height of the barometer above sea-level should be given as accurately as possible.

2. Precise information as to the methods employed in the calculation of the means (the hours of observation, and the formulæ used for reductions) should always be given.

It is further desirable to give the means for the separate hours of observation (for temperature, humidity, and atmospheric pressure), to facilitate the reduction to true means, which might be undertaken subsequently.

3. In publishing means for several years, it is very desirable to give

the separate means for periods of five years each (lustra) (commencing with the first year of each pentade—1881-85, 1886-90, etc.), in accordance with the resolution of the Congress of Vienna. In this way it would be possible to obtain with the greatest facility simultaneous and corresponding mean values such as are indispensable for any serious investigations on the distribution of meteorological elements, especially temperature, atmospheric pressure, and rainfall.

The following resolutions were passed:

"The Committee finds, that it is desirable to recommend the publication of hourly observations *in extenso* for a limited number of stations only in each country chosen with reference to the physical conditions of the country."

"In order to be able to compare the number of days of rain, the Committee recommends the publication of the number of days of rain, snow, etc., when the fall amounts to one millimetre (.04 inch), or more, in the summaries of results, in addition to the system already in use."

We give in full, below, the paper of Professor Buys-Ballot on a method of representing the variability of the weather, especially by giving the average value of the deviations irrespective of sign, which was adopted by the committee:

The variability of temperature and of barometrical pressure at a given station may be represented in various ways.

A. The mean daily range as given by the mean hourly observations (Met. Jaarboek, 1868-70). The mean excess of the maximum above the minimum readings is given for three stations in the Netherlands in each volume (Resumé in the Versl. und Meded. der Kon. Akad. of Amsterdam, Series ii., Tom. ix., p. 183, Table iv.).

B. In the Jaarboek, 1864 and 1865, I have given for each month the alternating maximum and minimum readings, with the dates on which they occurred, the mean of the subsequent differences being added separately.

From these the mean variation from each day to the following may be found, with considerable accuracy, by dividing by the number of days in each month. See the same Verslagen, quoted above.

Professor Hann has given this mean variation for 90 places, calculated in absolutely exact numbers, in his classical inquiry (Untersuchungen über die Veränderlichkeit der Tages-temperatur. Sitzungsber. der K. Akad. der Wiss. Wien, Vol. LXXI., 1875. Abstract in Oest. Met. Zeitschrift, Vol. XI., p. 336).

Dr. Hann gave also tables showing the number of times that a change of 1°, 2°, etc., occurred, and what is the probability of such an occurrence. MM. Köppen, Hegyfoky and Oscar Doering, have made similar

calculations, in Vols. XV. and XVIII. of the Oest. Met. Zeitschrift, and Vol. V., p. 281, of the Met. Zeitschrift, respectively. Lately Dr. Wahlèn, in his valuable work (Wahre Tages-mittel und tägliche Variation der Temperatur an 18 Stationen des russischen Reiches. St. Petersburg, 1886. Dritter Suppl. band zum Repertorium für Met.), has given similar calculations.

I myself, in the Vers. and Med., *l. c.*, contented myself with giving in Table V, the mean variability for three stations and for 30 years, showing that this variability from day to day, as well as the daily range, is greater for Maestricht, and less for the Helder on the sea coast, than it is for Utrecht.

C. Dove has defined variability of temperature to be the mean of the monthly departures from the values for a series of years, or rather from well-determined normal values. This is a very valuable method, which I myself have adopted, but it ought to be completed by D and E.

D. A fourth method, which I venture to recommend, consists in giving for each month the sums of the departures (écarts) from the normal value, or, what is perhaps better, these sums divided by the number of days in the month.

Beginning with the year 1863, I have given these sums for groups of stations, and separately for the stations where the sums were least and greatest, respectively. The tables show clearly that as for the temperature the sums are least for islands, almost irrespective of their latitude, and as for the barometer they increase with the latitude.

E. It is very interesting to show in a table for how long and at what figure a departure may continue of the same sign. This I have shown in each Jaarboek since 1849 for Utrecht, occasionally for selected stations in Europe, and in the Jaarboek for 1879 II. for a great number of places in the northern hemisphere.

From these tables D and E, partially only in manuscript, I have extracted the maximum sums, those above 10° C. (or 100 mm.) up to 29.3° C. for the temperature departures at Helder, Utrecht, and Maestricht, from 1852 to 1874, and printed them in the Versl. und Med., Series II., Tom. IX., Table VII., and for the following years, here and there, in the Jaarboeken from 1876. For Utrecht these tables give all the sums, both small and great, for temperature and barometer from each Jaarboek.

The accuracy of these sums depends to a certain extent on the accuracy of our knowledge of the normal values.

If an error of, say, 1° C. or 1 mm., be made in estimating these normal values, it will be necessary to subtract or add as many degrees or millimetres as there were days on which the departures lasted with the same sign; and what is still more awkward, such a series may seem to continue longer or shorter when the sign itself is altered by this uncertainty.

Nevertheless, this source of error does not exert so much influence as might be supposed, and moreover the sums are interesting for other inquiries.

I shall not dwell longer on these different methods, each of which has a different meaning, but shall conclude with a few words in recommendation of the method D, combined with C.

The sum of the departures (Σ) for a month, or their average values $\frac{1}{n}\Sigma$ for one day in such a month, are not so much dependent on an accurate knowledge of the normal value, especially if the departures have different signs in nearly equal proportions, the positive (p) increasing, while the negative (n) decrease, and *vice versâ*, by the same amount. It is generally the case that only very few figuers are changed in their sign by such an error. For instance, Paris, March, 1879, the sum is 226 mm. It would have been the same if the normal had been 1 mm. higher, and if it had been 1 mm. lower, which would be quite impossible, the result would have been 288. Even Posen, April, 1879, for which the result is 236 mm., the normal being 754.9, it would have been 265 if the normal had been accepted as 755.9, and only 237 if the normal had been 753.9. This is the most extreme case I could find.

It is, however, only for a very few stations, for mountain stations, and for such as are very distant from those for which the normals are well determined, that an error of 1° or 1 mm. is possible, and this error will be diminished or reduced to zero after some years of careful examination of the normals. Accordingly this method will become as accurate as method C.

In recommendation of this method I may say that these sums are obtained without any trouble of calculation, which is not the case if the variability from day to day is calculated. Every one who calculates departures (and this practice is coming into general use, and is very desirable for other purposes,) is compelled to use the sum of them as a check on his work. He obtains separately the sum Σp, and the mean value P of positive departures by adding the sum Σn of the negative departures, and their mean value N, by subtracting the deviation of the month, and of course when both these results are obtained you can get the sum of each.

For instance, if we find for a place the mean sum for a month S, and the mean departure D, we know that $\frac{1}{2}(S + D)$ and $\frac{1}{2}(S - D)$ multiplied by the number of the days of the month represent the sums Σp and Σn of all the positive and negative departures respectively.

If S is nearly equal to D, the departures have nearly all the same sign; if D, on the contrary, is very small, then the sums of both kinds are very nearly equal. I say, therefore, that this method should be combined with method C.

Let, for instance, as in May, 1879, for Aarau, the departure from the

temperature for each day, though great, have been not greatly different, D on the average -4.15° then the variation V will be relatively small 1.71 , while S = D, Σ = 31 D.

When 15 of the departures are almost of the same amplitude and positive, and the 15 following negative, then just as when they change frequently in sign, being alternately + and —, the departure in both cases will be nearly 0, while in the first case, from method C, V will be small, in the second great.

Christiansund, May, 1879, gives S = 2 58°, D.= —0.09°, V = 2.40°.

Klagenfurt, April " " S = 2.35°, D,= +0.25°, V = 1.33°.

S, D, and V appear to be far from being proportional to each other, and therefore they should, each of them, be represented, in order to indicate the climate of the place, and the character of the month.

In sanitary respects, the second case is more dangerous than the first, while in both cases the meteorological disturbance is very slight.

Between the two cases, method E decides by representing the greatest sum of departures of the same sign in continuation.

On the whole, however, in a long series of years all these different cases will be represented, and both methods, as well as the third D, will give a similar result. I do not dispute the value of method B, and in fact think highly of it, but I think that method D is of equal or greater value than B, especially if it is combined with C and E. The three latter being much more easily obtained than B, and obtained by one and the same calculation, the numbers of D and E being obtained by a simple addition of the departures, but serving as a check on the calculation. (Signed) BUYS BALLOT.

The mountain meteorological stations established are:

		Height above sea. Feet.
Germany	Brocken	3,747
	Schneekoppe	5,246
	Wendelstein	6,027
Austria	Hoch Obir	6,706
	Sonnblick	10,154
	Schafberg	5,827
Switzerland	Säntis	8,094
France	Puy de Dome (founded in 1876)	4,823
	Mont Ventoux	6,234
	Pic du Midi	9,380
Portugal	Serra da Estrella	4,728
Italy	Mount Vesuvius	4,265
	Monte Cimone	7,094
	Mount Etna	9,679
Scotland	Ben Nevis	4,406
United States	Blue Hill	635
	Mount Washington	6,280
	Pike's Peak	14,134

The last two stations have ceased their activity since 1888.

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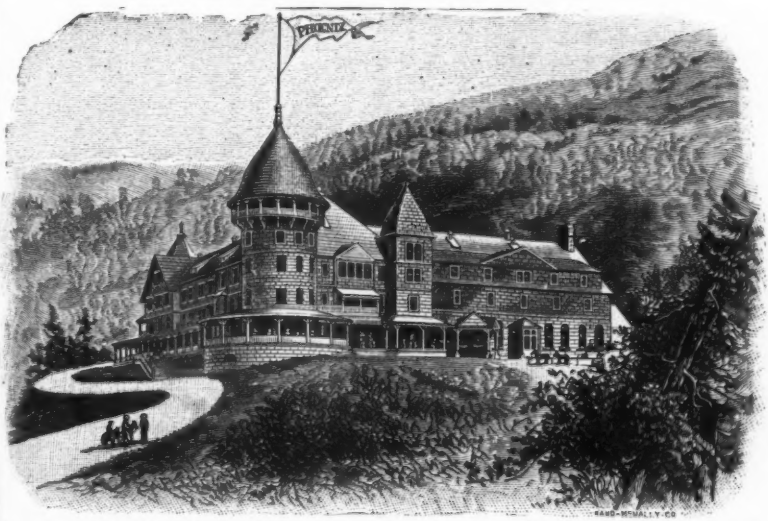

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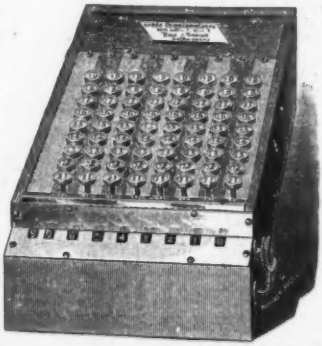

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